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Assessing Virtual Learning Environments (VLE) for Construction Management Education

Bradley Benhart, MBA
Purdue University
West Lafayette, Indiana
United States of America

Stephen Austin, MSc., A. Bogdanovic, Dipl.Ing.Arch., Janet Campbell, MEng CEng MICE, and Andy Reid, MSc
Coventry University
Coventry, United Kingdom

This paper contributes to the current discussions and research on the use of 3D digital technologies in teaching and learning. It specifically focuses on the use of a Virtual Learning Environment (VLE) in construction management higher education. There were three objectives: (1) to check the impact of this approach on student learning (2) to determine which factors increased the perception of immersion (3) to assess whether this type of learning could affect cognitive change. A VLE of a construction site and related scenarios were used to develop a set of learning outcomes focused on soft-skills. Utilizing Virtual Reality (VR) to create an immersive environment, the VLE enables a student to work on a construction site, undertaking real life scenarios and interacting with people to enhance leadership, behavioural health, safety, quality, and productivity skills. A series of individual scenarios were developed to help contextualize the learning outcomes. These scenarios were based around a day managing a construction site. The immersive simulations were underpinned with pedagogical tools and structures, namely the Kolb Experiential learning Model and Gibbs Model of Reflection (Kolb, 1984; Gibbs, 1988). The experiential learning allows the student to make decisions and understand the consequences. The learning takes place in a safe environment which negates impact on a real job site and is reinforced through feedback, knowledge sharing, and mentoring. The assessment involved questionnaires designed to evaluate the impact of experiential learning, assess which aspects of the simulation had the greatest impact in relation to the feeling of immersion, and to assess whether this type of teaching could affect cognitive change. The results indicate that the students perceived the method to be effective and highlighted 3 key factors relating to immersion - the actors, the site office, and the site paperwork. The outcome of the third objective was not conclusive and further research on long term cognitive change is recommended.

Key Words: immersive simulation, scenarios, Virtual Learning Environment (VLE)

Introduction - the Simulation Centre

Coventry University Simulation Centre (www.thesimulationcentre.co.uk) is a VLE (figure 1) that incorporates 3-D VR displayed on a 10m screen, actors, real site cabins and construction assets such as programs and drawings. The pedagogy approach is based on problem-based learning (PBL) and learn by doing.

Figure 1. Images of the Simulation Centre

The students undertake a series of individual, but interlinked, scenarios which have a cohesive narrative to help contextualize the learning outcomes. These scenarios focus on managing a construction site, including the pressures, issues, and interruptions that are experienced on a real building site. The approach allows the students to experiment with ideas and development concepts in the VLE that will have no consequence or risk to themselves or others, it is a 'safe' environment. The outcome is a personalized learning experience, without real world repercussions.

To initiate situations, the students are located in one of eight site offices on a construction site. They can walk through and view the job site on the 10m screen. The interaction with actors and site office assets further enhance the realism. The student utilizes joystick VR locomotion, as this is perceived as easy to use (Costas and Cedergren, 2018) to move through the VR construction site.

To overcome the perceived technology barrier, a "taster" session is the first simulation. This includes a task to discover discrete details relating to the construction site. This encourages the student to search the documentation in the site office, use the telephone, and immerse themselves in the virtual construction site. An actor will also visit the student, with a benign query, one that can be readily resolved, so that the student has experienced the learning process and is more confident with their role. Following this session, there is feedback while student queries are clarified.

Literature Review

Rapid advances in digital technology and a subsequent decrease in the associated costs has enabled educational establishments to invest and incorporate 3D technologies in their teaching (Abulrub, 2011). Although some of these virtual worlds were not initially designed for education, they have been shown to be effective for constructionist learning. They allow students to actively explore, test and extend their understanding. A study undertaken by O. Halabi found that using VR and a project-based approach concurrently led to improved communication and problem-solving skills as compared to a traditional approach (Halabi, 2020). It is also recognized that construction engineering education and training institutions have begun to implement VR due to its perceived benefits of providing immersive and engaging environments (Wang and Wu 2018). Current research tends to focus on how 3D technologies aid a student's understanding of a structure or detection of defects. Examples would include using Building information Modelling or virtual worlds. However, there is limited understanding of the application of VLE from a user-orientated perspective. (Wang and Rui 2020;

Delgado et al., 2020). It is important to recognize that teachers need to understand how to apply learning theories that are relevant to a digital age (Starkey, 2011).

A review of VLE (Mikropoulos and Natsis, 2011) state that visual representations predominate and establish VR and is a useful approach to learning for construction students. VLE have the potential to create virtual world experiences for learning and teaching purposes. Kolb's experiential learning theory states that people gain and transform knowledge through experiences (Kolb, 1984). In construction, learning and teaching can be difficult to gain experiences in the real world. The significance of these new technologies is recognized. However, there remains a lack of empirical evidence specific to the impact that new technology might have on learning behaviour and preferred learning styles. This study surveyed students to identify their preferred learning style before and after a simulation exercise, and which features enhanced the feeling of immersion. The features of a VLE that are thought to contribute to positive learning outcomes include immersion or presence ('sense of being there'), fidelity, flow, active learner participation/motivation and immediacy of control (Chau et al, 2013). They conclude that using a VLE is learner-centred, allowing the learner to construct knowledge by themselves. They also draw attention to the difficulty of measuring actual learning as opposed to perceived learning. To summarize there are technical characteristics, human characteristics, and pedagogical characteristic to consider when creating and using a VLE.

Methodology

Though the Simulation Centre has been running for a number of years, no research has formally been undertaken on its effectiveness. This paper is the first step in addressing the research gaps related to the potential effectiveness of simulation centre training to obtain a base understanding of its effectiveness in terms of self-efficacy.

This study follows a mixed method approach, utilizing two anonymous structured questionnaires, one that the students completed before the simulation and the second completed immediately after the simulation. The cohort consisted of 32 fourth year MEng Civil Engineering students aged between 21-25 years at the School of Energy, Construction and Environment at Coventry University. The first questionnaire contained initial questions related to any prior industrial experience and motivation, and preferred style of learning. This was followed by a series of questions relating to self-efficacy using a Likert 5-point scale.

The second questionnaire was undertaken immediately after the simulation by the same 32 students. They were again asked their preferred learning styles and whether this had changed due to the experiential learning. The subsequent questions (Likert scale) related to the effectiveness of the learning experience with a qualitative question relating to any identifiable skills developed during the simulation. The same questions relating to self-efficacy from the first questionnaire were repeated to measure the impact on the student. The students were also asked to identify, from a list, what factors created the feeling of immersion or presence during the simulation. As such, the questionnaire was both quantitative and qualitative (The Open University, 2007). The balance between both data forms should help to ensure the reliability and validity of the process.

Results – Pre-simulation

The students undertaking the simulation had previously worked in the construction industry, with a range of industry experience from summer jobs to the largest number (22) having undertaken a one-year internship. This enabled the students to rapidly participate in VLE as they were familiar with the job site environment.

When looking at their preferred learning pedagogy, the overwhelming number selected to learn through doing (72%), making the learning opportunities within the VLE applicable and appropriate to them. Only 8% of the students preferred to learn through listening and reading; this is partially accommodated through the feedback being discussed verbally and individual written feedback distributed to each student at the end of the session.

The learning anxiety section investigated whether using a VLE could impact negatively on the learning experience. The results in figure 2 indicate the majority of the students did not have learning anxiety before participating in the VLE. Several students had previously undertaken courses in the simulation centre. This could account for the high percentage that expressed their lack of anxiety. Alternatively, the high degree of construction industry experience could also account for this result, as the simulation was specifically related to working on a construction site.

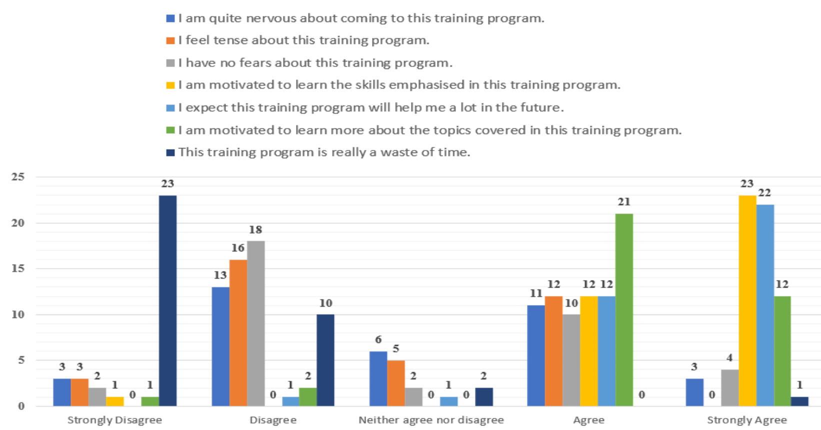

Figure 2. Learning Anxiety and Motivation

Results – Post-simulation

A number of questions were replicated after the simulation to measure any variation, in particular those relating to self-efficacy. The results for the preferred learning style did not alter considerably, as the approach matched the majority of the learners' preferred style of learning.

The questions on the effectiveness of the overall experience are shown in figure 3. This demonstrates that the students' perception of the simulation approach was effective, which coincided with their motivation results before they undertook the simulation.

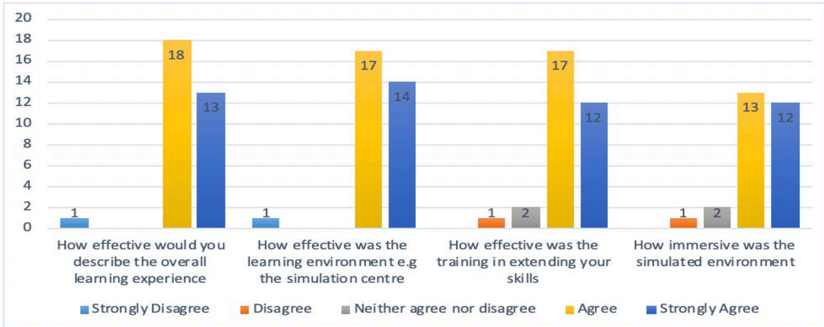

Figure 3. Learning effectiveness

Self-Efficacy Analysis

To fully analyse the impact of the training, a comparison of the separate questions regarding the students' self-efficacy has been undertaken. The eight questions have been collated to show the responses pre and post training to ascertain whether the students' self-efficacy had altered. *Strongly agree* and *agree* have been classified as a positive response, while *strongly disagree, disagree* and *neither agree nor disagree* have been classified as a negative response.

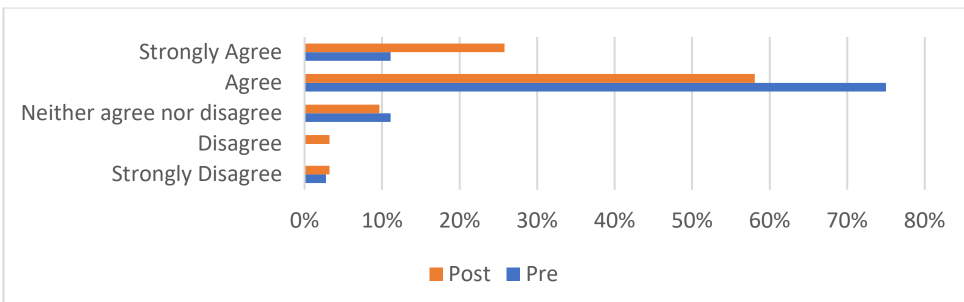

Figure 4. I will be able to achieve most of the work-related goals that I have set for myself.

Figure 4 shows that the results pre and post simulation are similar, before the simulation 86% of the students gave a positive response regarding their ability to achieve work-related goals. After the simulation, this was at a similar level of 84%; however, the percentage strongly agreeing increased from 11% to 26%. The next question focused on facing difficult work tasks.

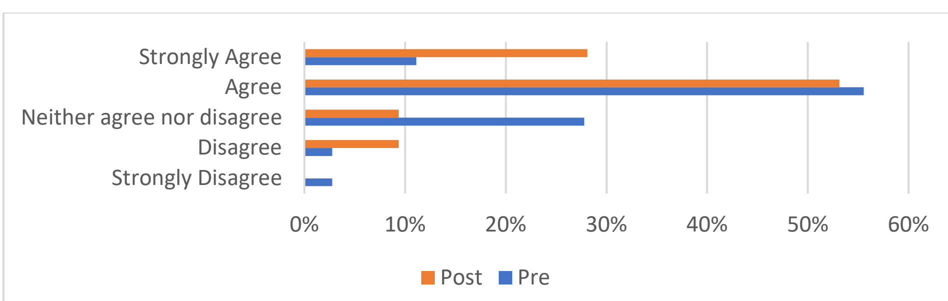

Figure 5. When facing difficult work tasks, I am certain that I will accomplish them.

Figure 5 indicates a greater difference pre and post simulation. Prior to the simulation, 67% of the students were in agreement or strongly agreed that they could accomplish difficult work tasks. This rose to 81% after the simulation, with the *strongly agree* category increasing by 17%. Also, the percentage of students who gave a negative rating decreased by 15%.

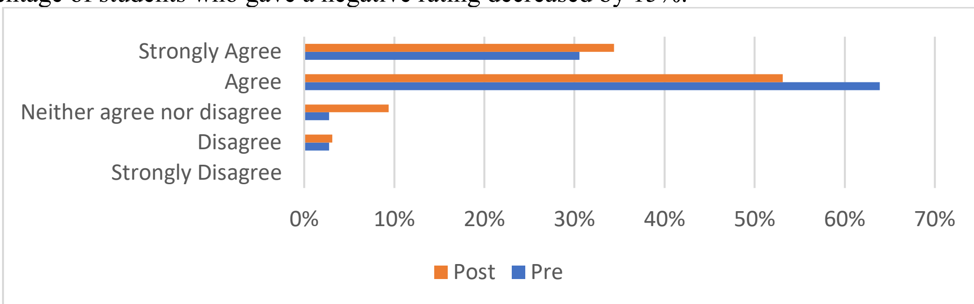

Figure 6. In general, I think that I can obtain work outcomes that are important to me.

Figure 6 indicates a decrease in the students' responses, with 6% reduction in positive responses but a slight increase in the *strongly agree* category. Prior to the simulation, this question had a high positive response (94%). This decrease could be due to the students' self-reflection on their abilities and realizing they might not be as strong as they previously thought after their simulation experience.

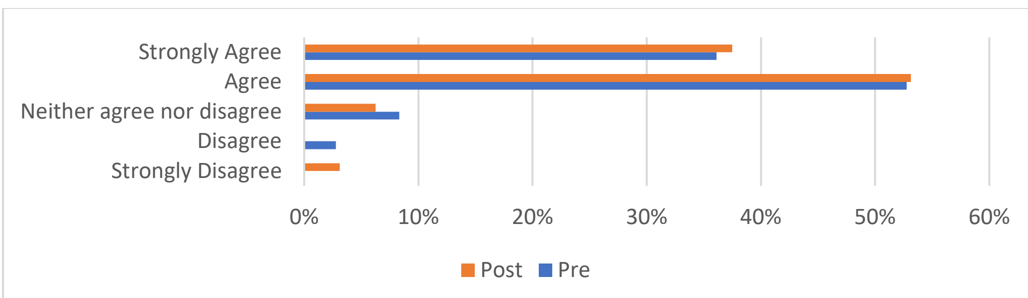

Figure 7. I believe I can succeed at most any work-related endeavour to which I set my mind.

Figure 7 shows that there was no change in the student responses regarding their belief they could succeed at any task they set their mind to with only a 2% change.

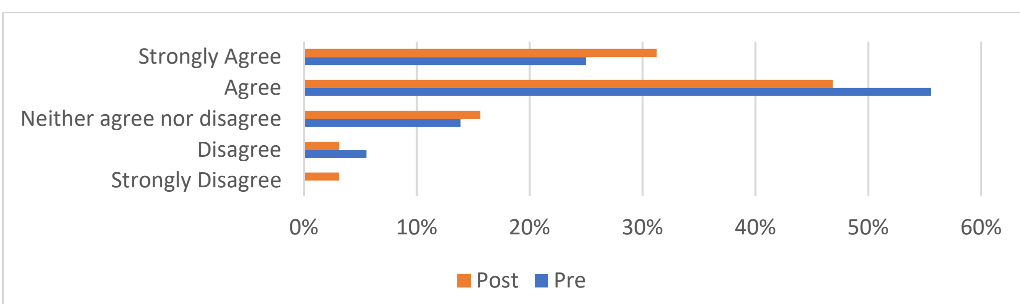

Figure 8. I will be able to successfully overcome many work-related challenges.

Figure 8 indicates a small decrease in positive responses (3%), which could again be attributed to the students' real understanding of their self-efficacy after undertaking the simulation. Again, there has been an increase on the *strongly agree* category (6%).

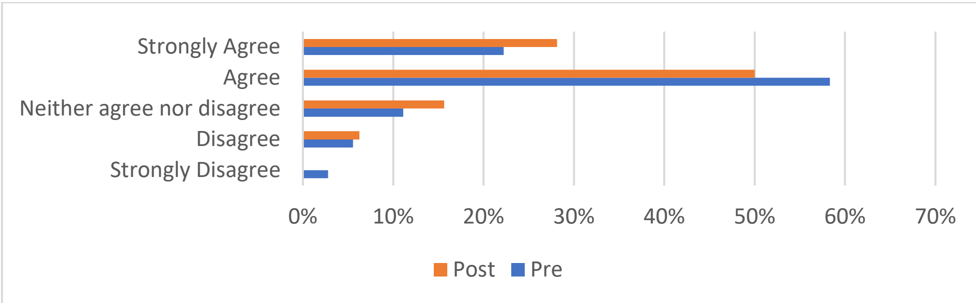

Figure 9. I am confident that I can perform effectively on many different work tasks.

Figure 9 indicates a similar trend. As with the previous question, this showed an increase (9%) with the *strongly agree* category increasing by 11%, a slight change in the students' response after the simulation.

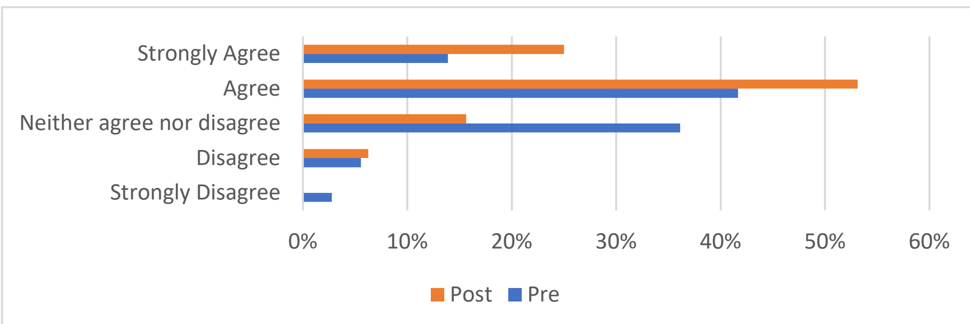

Figure 10. Compared to other people, I can do most work tasks very well.

Figure 10 shows that this increased by 22% following the simulation, a positive outcome of the simulation. This is possibly due to the pedagogy of group feedback and reflection, allowing the students to compare how they undertook the scenarios with one other.

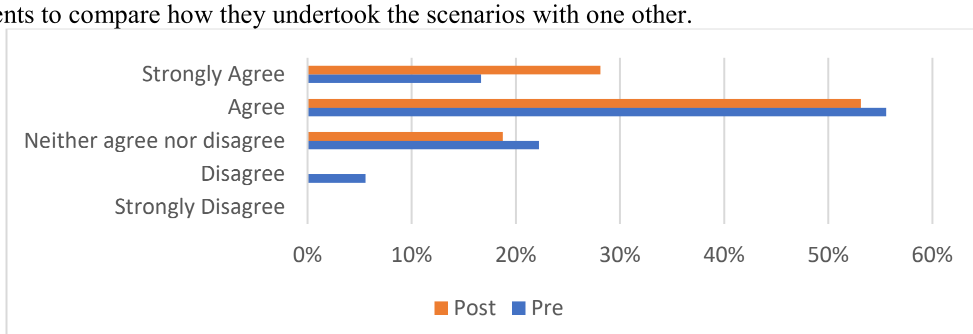

Figure 11. Even when things are tough, I can perform quite well at work.

The final question in figure 11 looked at their performance under tough conditions, something that the Simulation Centre excels at delivering. As with the previous question, this showed an increase (9%) with the *strongly agree* category increasing by 11%.

The results from the self-efficacy questions were supported with the qualitative comments from the students in the second questionnaire when they were asked what specific skills had been developed in the training. The common themes were development around problem solving, communication, people/interpersonal skills, confidence, communication/ listening and leadership. The questionnaire results also included the students' experience regarding empathy, confidence and thinking/understanding.

Factors contributing to Immersion/Presence

A key enabler to a successful learning outcome is ensuring the student is immersed in the VLE. To measure what factors have the greatest impact, we asked the participants to highlight which factors they perceived as integral to the immersive environment. See figure 13. The list of assets and stimuli were garnered from the simulation centre facility. These factors blend together to create the overall immersive environment. The objective was to ascertain which factor(s) had the greatest impression on the learner. Respondents were allowed to tick as many stimuli as they felt helped in the learning experience. Using this information in the future will assist in accelerating the immersion of the learner and could highlight the hierarchy of assets required when using a VLE.

The graph shows that the top three aspects of the simulation centre that create an immersive environment are the actors, the site office and the paperwork. Surprisingly, the VR is ranked fourth. It could be argued that these top three factors could be used to create immersion, without the visualization. However, the results of the visualization and the screen added together would create the highest score. It is not clear to the authors whether this differentiation caused confusion with the participants or whether the two aspects are interlinked. Further analysis of the VR will be beneficial, to ascertain the impact of the screen and visualization. This will investigate whether the visual representation has to be 'ultra' real, which is a true replication of the learner's actual site set up, as well as the extent of whether interaction with the visualisation is necessary.

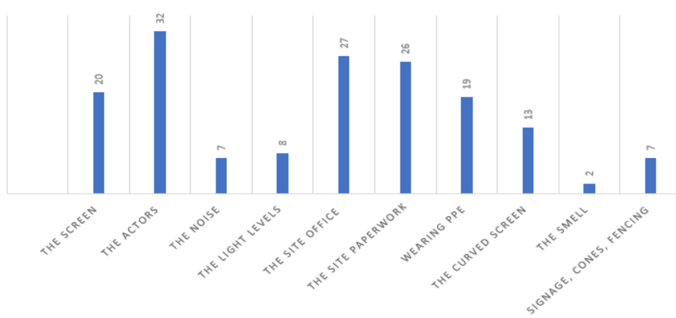

Figure 13. Greatest Impact Factors

Conclusion

This case study investigated three aspects relating to experiential learning in an immersive environment using the Simulation Centre at Coventry University. A general evaluation of the impact on the students after undertaking this type of learning was undertaken as well as an assessment of which factors had the greatest impact relating to the perception of immersion. A majority of the students expressed a preference for this approach, namely learn by doing. This was evident in their responses, specifically their lack of concern before undertaking the simulation and their high degree of motivation to undergo the simulation. The post evaluation again suggests that the students observed this approach as effective in aiding in their soft skills development. There was a clear outcome that the actors, project documents, and site office are essential factors that create the immersion. The VR screen was not as highly ranked as the faculty would have expected. The people-to-people role playing provided the greatest impact. This is a key take away for any ASC school interested in building a simulation centre. It was assumed that the visualisation would be key to the immersion, however, as seen, it was not the primary factor and further analysis of this is suggested.
The third objective was to assess whether this type of learning could affect cognitive change. The results are inconclusive, and it is perhaps the fundamental evaluation, namely permanent cognitive change, that remains to be evaluated in future studies. As previously mentioned, this paper is the first step in addressing the research gaps related to the potential effectiveness of simulation centre training to obtain a base understanding of its effectiveness in terms of self-efficacy. The quantitative data presented here is backed up by further qualitative information obtained in the questionnaires regarding the strengths and weaknesses of the training undertaken. This is further backed up with qualitative information through the reflections submissions that the students produce as part of the assessment linked to the learning. This data and further quantitative data will be collected later from industrial users to allow comparative analysis and possible further research around age, gender and the overall simulation effectiveness. The authors continued to be excited by the popularity of the VR and the impact it is making on students. Through Associated Schools of Construction (ASC), the authors have been able to establish partnerships with other universities for this and future research to aid and support new developments in construction education.

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